Kilo-Pixel Miniaturized Thermal Imagers based on Advanced Thermoelectrics

Giacomo Mariani, Matthew Kenyon, Sabah Bux, William Johnson
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91125 USA

***Abstract*— This work presents a novel focal plane module architecture based on kilo-pixel arrays able to image from UV to far-infrared scenes. The focal plane arrays are integrated with custom-made, chopper-stabilized read-out integrated circuits into sub-assembly modules to be mounted on the optical telescope of the instrument.**

I. INTRODUCTION

THERMOPILE based thermal imagers are passive devices that do not required any electrical bias while generating an output voltage proportional to the radiation flux. The conversion from thermal radiation to output voltage occurs by means of thermoelectric materials via Seebeck effect: when two ends of a conductor are held at different temperatures electron at the hot junction at higher thermal velocities diffuse to the cold junction producing an electro-magnetic force between the two ends. Bismuth-antimony-tellurium (Bi-Sb-Te) alloyed ternaries are particularly suitable for this type of application [1]. The effort at JPL is to provide kilo-pixel arrays fully integrated with read-out integrated circuits (ROICs). Rigid-flex hybrid configurations are explored for plug-and-play focal plane module assemblies. Thermopiles are responsive over a broad wavelength range (0.3-200µm), making them especially suitable for Earth and planetary missions.

II. RESULTS

Kilo-pixel thermopile arrays based on Bi-Sb-Te ternaries are bulk micro-machined at the MicroDevices Laboratory at JPL. The pixels are arranged in a 64 (cross-track) x 16 (in-track) format. A gold black coating is deposited atop the array. Gold black is a porous nano-structured conducting film which acts as a broandband absorber from visible to far-infrared regions.

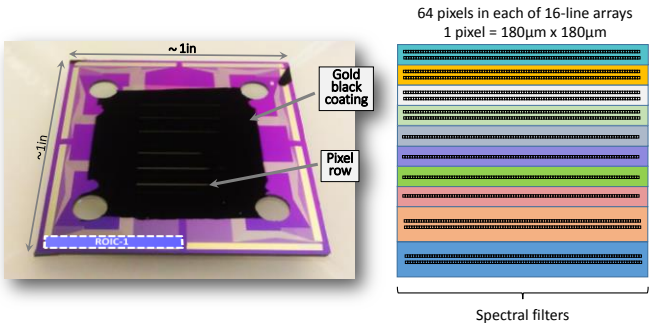

Figure 1: Micro-machined kilo-pixel array with gold black coating (left). Representation of spectral bands with butcher-block filter assembly.

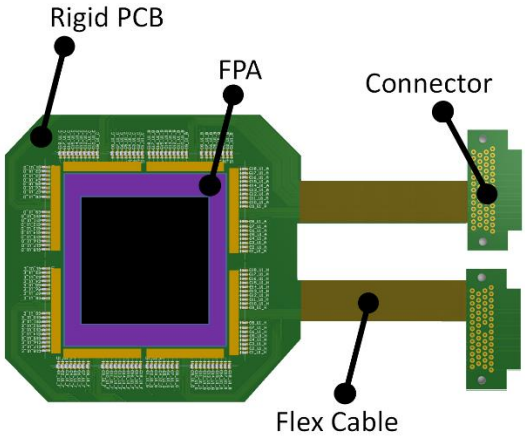

Figure 2: Depiction of fully-integrated rigid-flex focal plane module assembly.

Figure 1 shows an image of a typical thermopile array (left). The image also displays a possible spectral filter arrangement on top of the pixel rows: band-pass filters arranged in a butcher-block configuration (right) define the focal plane assembly (FPA) spectral bands to meet mission-driven science goals. *Figure 2* shows the rigid-flex FPM assembly hybridized to the Glenair connectors. Eight 128-channel ROICs chopper stabilize, amplify, demodulate, digitize, and time multiplex the signals to the serial digital interface (SDI) output of the ROIC. The objective of this work is to realize high-detectivity focal plane assemblies for far infrared detection at room temperature. The rigid-flex configuration is versatile to be accommodated in a variety of miniaturized thermal imagers without costly cryo-coolers to achieve far-infrared imaging. *Table A* summarizes a few cardinal resources and capabilities at the sub-system level.

Resource	Capability
# of Channels	1024
# of Columns	64
# of Rows	16
Noise Level	60-70 V/rtHz
Rad Tolerant	Yes
Room Temp	Yes
Far-IR	Yes
Total Power	<2.0W

Table A: FPA capabilities.

III. TECHNOLOGY READINESS LEVEL MATURATION

Vibration testing and thermal cycling were performed on the kilo-pixel array assembly to environmentally test and bring the sub-system to TRL 6. Random vibration testing was carried out along all three reference orthogonal axes (X, Y, Z). The random vibration test specification applied to the part is presented in Table B. Random vibration testing was preceded and followed by a random signature survey at 0.0001 g2/Hz (0.44 grms) from 20-2000 Hz for 2 minutes to verify the structural integrity of the test article.

Frequency (Hz)	Qual Level
20	0.104 g^2/Hz
20 – 50	+6 dB /octave
50 – 800	0.64 g^2/Hz
800 – 2000	-6 dB /octave
2000	0.104 g^2/Hz
Overall g_{rms}	28.2

Table B: Random Vibration Specification

Thermal cycling is carried out in 20 thermal cycles (-55/+85C) in a nitrogen-purged thermal chamber, 30-min plateau/cycle. Visual and optical inspection show no quantifiable change pre- and post-vibration testing as well as pre- and post-thermal testing.

IV. Summary

Surface- and bulk-micromachining of RBI thermopile detector arrays and incorporation into a fully-integrated focal plane module assembly is presented as remote-sensing thermal imager as potential payload in a variety of Earth and planetary missions [2]. Environmental testing composed of thermal cycling and vibration testing is carried out for TRL maturation. The sub-assembly presented in this work constitutes a well versatile, connectorized, far-IR focal-plane module operating at room temperature.

V. Acknowledgment

The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. © 2017 California Institute of Technology. Government sponsorship acknowledged.

References

[1] M. C. Foote, M. Kenyon et al. “Thermopile detector arrays for space science applications”, International Workshop on Thermal Detectors for Space Based Planetary, Solar, and Earth Science Applications TDW 2003.
[2] Joint Polar Satellite System. Source: www.jpss.noaa.gov/satellites.html